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ON THE COVER:

Solar-flare prediction is a high-priority research program among Air Force radio astronomers. These two dishes—the smaller one measuring 1 foot in diameter and operating at 3,400 MHz, and the larger one measuring 3 feet in diameter and operating at 15,400 MHz—are 2 of 7 antennas being operated by radio astronomers at AFCRL to monitor radio emissions from the sun. The purpose of these studies is to find clues in the radio signals which will lead to prediction schemes that will help forecast solar effects on the terrestrial environment.

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The Spectrum Analysis Radar: a New Radar Principle

MICROWAVE PHYSICS LABORATORY, AFCRL

Before the first test model was built, AFCRL's new spectrum analysis radar seemed to promise too much, considering its simple componentry. What was promised was a radar that was difficult to jam, with almost no mutual interference between nearby radars of the same type, high-range resolution of closely spaced multiple targets, high accuracy, and the capability of measuring range down to zero with an accuracy of within a foot or so.

The radar concept was originated by J. Leon Poirier, who also assembled and tested the initial model. Test results matched the most optimistic expectations.

The spectrum analysis radar is based on a new radar principle. (See Figure 1.) Its key component is a spectrum analyzer. AFCRL's test model, in fact, used a standard spectrum analyzer of the type found in all well-equipped microwave laboratories. The signal source used in the test model was a gaseous-discharge noise tube producing a Gaussian noise signal.

Basically, the radar is a c-w noise radar. But it must not be confused with other c-w noise radars or frequency agile radars such as CHIRP or DITHER. Such radars usually require rather complex delaying and cross-correlation techniques. The spectrum analysis radar requires neither.

The radar has its origin in partial coherence theory. Many of the first formulations of this theory were developed at AFCRL in the late 1950's and, since then, partial coherence theory has figured heavily in the analysis of electromagnetic-wave propagation problems by AFCRL's Microwave Physics Laboratory. This theory describes the behavior of broad-band noise signals as they propagate. It predicts that, even after all traces of amplitude interaction due to phasing between two signals have vanished, it is still possible for their power spectra to interact.

The spectrum analysis radar is the direct result of the discovery that, when a noise signal illuminates a target or any discontinuity, the power spectrum of the reflected signal, and not its intensity, contains the target information. Of course, when we look at the spectrum of random noise, we cannot tell what information the apparently meaningless fluctuations might contain. (See Figure 2.) We need a reference signal. For the reference signal, Poirier uses the standard method of taking a small part of the transmitted signal. This reference signal is then added to the received signal and their sum observed on a spectrum analyzer. Although these two signals are uncorrelated, the power spectrum of their sum is modulated. (See Figure 3.) The modulation frequency depends only on the range to the target.

Now, if we put this signal through a peak detector and a filter, and display it on a second spectrum analyzer, an A-scope display will result. Pips along the horizontal line of the scope indicate the presence of targets. The location of these pips is linearly proportional to the range of the target. It would be fairly easy, if desirable, to convert the A-scope display to a standard radial or PPI display.

This processing technique yields the same information as does a cross correlation between transmitted and received signals; but it also has several other characteristics worth mentioning. For one, since the reference signal is completely uncorrelated with the

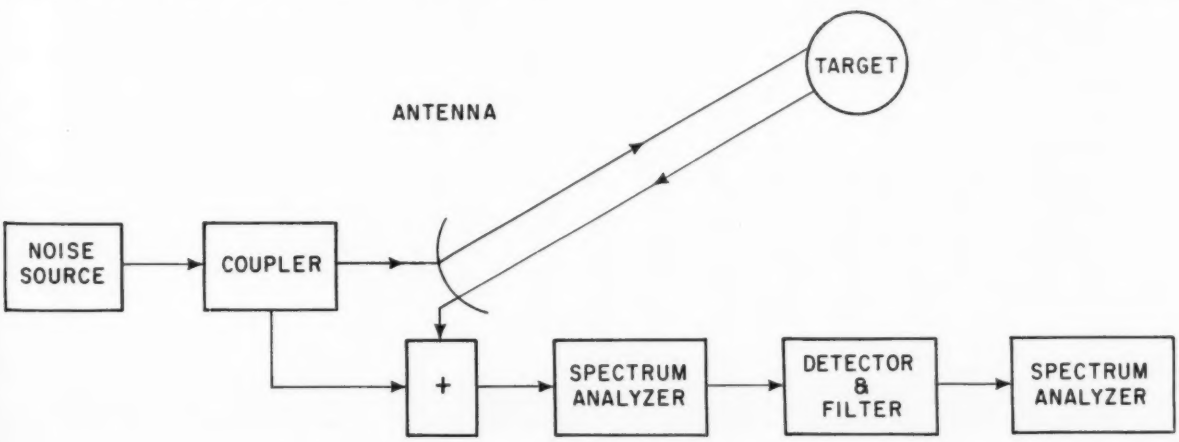

Figure 1. Block diagram of spectrum analysis radar.

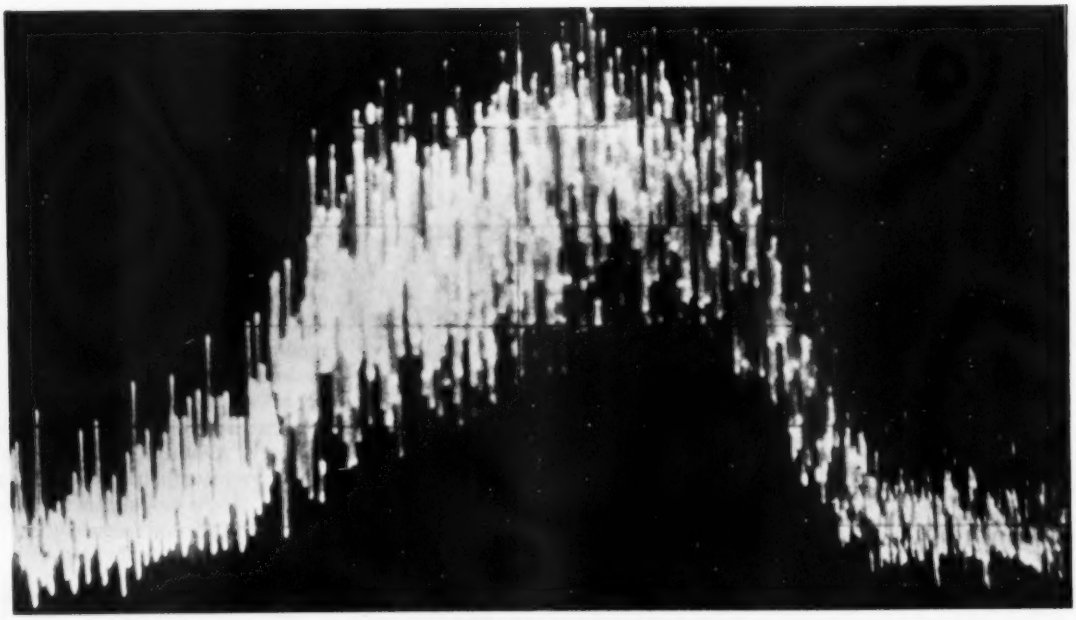

Figure 2. Transmitted Gaussian noise spectrum.

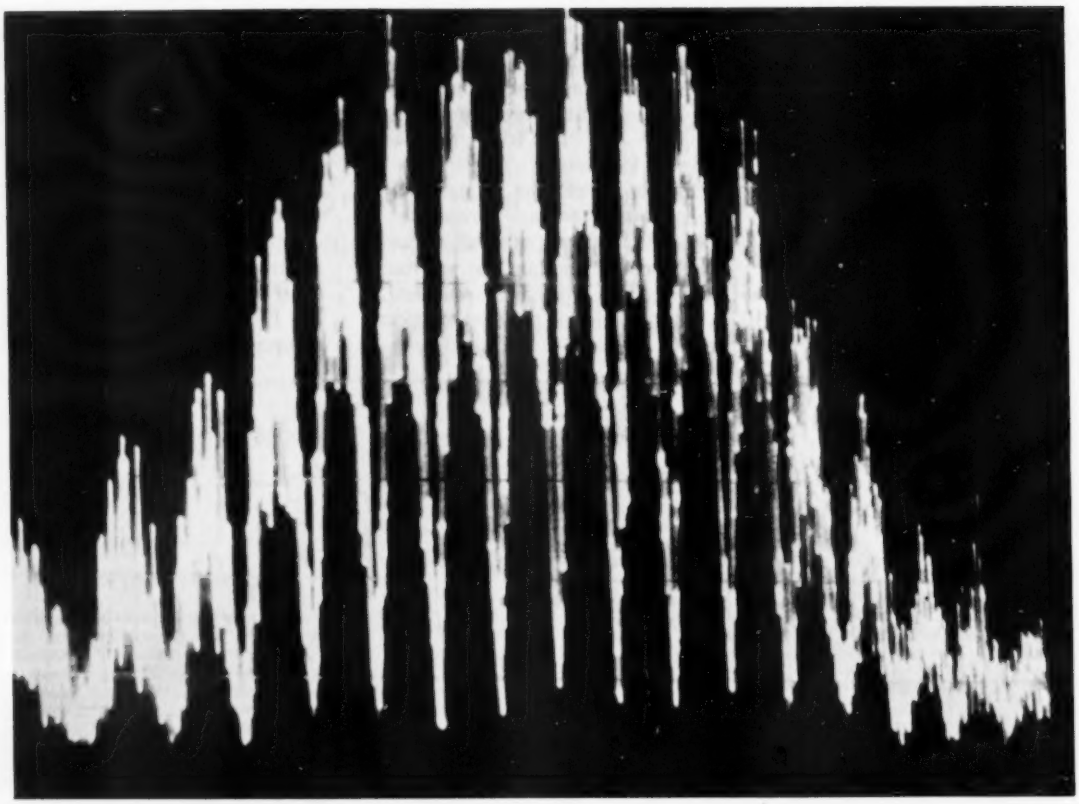

Figure 3. Received spectrum.

target and clutter signals, no intensity variations due to phasing can occur. This means that there are no nulls in the ranging as there are in coherent radars and cross-correlation noise radars.

Another characteristic of the system is that the angular location of a target can be determined by using two systems (or one time-shared between two antennas) separated by a small distance. The small difference in range to the target, as seen by each of the antennas, will cause the location of the nulls observed in the spectrum of one system to shift relative to the other. If the spacing between antennas is known, this shift can be converted into angular position.

Unlike conventional pulse radars, in which a range resolution cell is roughly equal to the illuminated zone, the range resolution of random signal radars is independent of the illuminated area so long as the clutter does not completely wash out the target signal. However, modulations due to the clutter are both reduced in amplitude and distributed in frequency. Because of this, there is a natural selection or enhancement of the signal reflected from a target.

Although the present analysis is based on c-w signals, there is no fundamental reason why pulses could not be used to diminish the illuminated clutter area and so improve system performance in high-clutter-background applications.

The critical components of the system are the spectrum analyzer and a high-power noise source. High-performance spectrum analyzers covering a 2-GHz bandwidth are now commercially available, although the AFCRL test system used a bandwidth of only 12 MHz. Optimum high-power noise sources, however, are not available.

The radar could be used for a wide variety of short-range applications (up to about 20 miles). Because of its basic simplicity and relative immunity to mutual interference, a foremost application could be its use as a collision-avoidance radar for military and commercial aircraft.

Mr. J. Leon Poirier shown adjusting balance between reference signal and received signal.

Mr. J. Leon Poirier is an electronic engineer with the Plasma Electromagnetics Branch, Microwave Physics Laboratory, AFCRL. He is the project engineer in charge of the Trailblazer II Re-entry Communications Program, investigating the propagation of electromagnetic energy through the plasma sheath, the voltage breakdown of antennas, plasma simulation, diagnostic tools for determining the properties of the plasma sheath, and techniques to eliminate the deleterious effects of the plasma. He is also carrying out basic studies on the propagation and reflection of broad-band random signals from fixed and random distributions of targets, and is analyzing and developing a new radar technique based on the results of random signal studies.

Mr. Poirier received his B.S. (magna cum laude, 1958), and his M.S. (1959), both in Electronic Engineering, and both from the Lowell Technological Institute. Before coming to AFCRL, he had done work in the environmental testing of missile subsystems for the Bell Aircraft Company. Also, as an Air Force lieutenant assigned to the Electromagnetic Radiation Laboratory, RADC, he had been concerned with problems of communication through plasmas.

Mr. Poirier is a member of RESA and IEEE, and has a number of publications to his credit.

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ENERGY-BAND CALCULATIONS

The objective of the Solid State Physics Research Laboratory is to investigate and make known the results of studies of the growth, structure, and properties of compound semiconductors and the effects of radiation on these compounds. Investigations in the II-VI class of compounds, which includes CdS, CdSe, ZnS, ZnSe, ZnTe and ZnO, are emphasized. Proposed applications for these compounds include high-temperature transistors, injector lasers, solar batteries, extremely high-frequency solid-state delay lines and amplifiers, photoconductive and image-converting devices, and solid-state electronic components.

In fulfilling its objective, the Solid State Physics Research Laboratory has an extensive research program in theoretical energy-band calculations. Energy bands have been calculated for semiconductors of classes IV, II-VI, and III-V, which form in the wurtzite, zincblende, or diamond structures. As in all theoretical investigations, the relevance of such work is to explain experimental data and to guide experimental work into more productive and useful areas.

The general approach taken in calculating energy bands of a given compound is the following: first, the energy bands are calculated, using a self-consistent orthogonalized plane wave (OPW) model. (1) Then, from these energy bands, the absorptive part of the dielectric constant (ϵ_2) is calculated. ϵ_2 is calculated since it is a parameter which can be determined directly from experimental data. The experimental and theoretical ϵ_2's are then compared. This comparison is necessary in order to check the validity of the OPW model. Once the validity of the model is established, it is possible to determine from the theoretical calculations the transitions which are responsible for the significant features of the ϵ_2 curves. This information can then be used by both the theorist and the experimentalist to gain a better understanding of the properties of these semiconductors.

In the past several years, the band structures of some of the semiconductors of interest have been studied using the pseudopotential method (2), the Koringa, Kohn and Rostoker (KKR) method (3), and the OPW method. (4) The pseudopotential method adjusts parameters to fit certain experimental results. Both the KKR and OPW calculations use free-atomic potentials packed into a crystal lattice. The OPW results are then fitted to the experiment by adjusting potential coefficients. The KKR method adjusts the outer region constant potential to fit the experiment.

We use a self-consistent orthogonalized plane-wave model. This is a more satisfactory mathematical and physical model in that there is no adjustment to fit the experimental data. The fundamental idea of this method is to use a composite set as basis functions for an expansion of the solution of the periodic potential problem. The composite set consists of Bloch sums of atomic orbitals of the inner electrons of the atom and of a limited number of plane waves. If the inner atomic orbitals do not overlap appreciably, the Bloch sums formed from them will form very good basis functions for the wave functions of these inner electrons. The addition of a fairly small number of plane waves, with the same reduced wave vector as the Bloch sums, will then make it possible to carry out a fairly good expansion of the wave functions in the higher energy bands. This method gives, as we should expect, more rapid convergence than an attempt to expand the complete wave function in plane waves. Since the plane waves do not have to take care of the inner features of the wave function, we do not need many of them to give a satisfactory approximation.

We then assume that we can approximate the wave functions of the outer electrons by using linear combinations of the plane waves, and the Bloch sums formed from atomic orbitals of the inner electrons. Since we know that the true wave functions will be orthogonal to each other, it is convenient to set up linear combinations of a single plane wave and the Bloch sums, with coefficients chosen so that the combination is orthogonal to all the Bloch sums used. Such a combination is called an orthogonalized plane wave (OPW). The process of adding some of the Bloch sums to the plane wave, to produce orthogonalization, automatically introduces a behavior near the nuclei of the atoms very similar to that which is found in the true wave functions.

The input to this model consists only of the lattice parameters, the nuclear charge of anion and cation, and the atomic states that are to be considered core states. The model is nonrelativistic and uses Slater's (electron density) $^{1/3}$ expression for the exchange potential. (5) The same self-consistent crystalline potential is used for both core and valence electrons. In this model, careful consideration is given to insure that the results are self-consistent and have a high degree of convergence. By self-consistency we mean that the core and valence states are calculated alternately until a self-consistent potential is obtained. A principal source of error in previous energy-band calculations has been the lack of convergence of wave-function

expansions. Because the valence and conduction wave functions are expanded in a modified Fourier series in reciprocal lattice vectors, a good model should use sufficiently many terms in the series so that convergence is obtained to within .02 eV.

The energy bands are calculated at four high symmetry points (Γ, X, L, and W) in the Brillouin zone. The resulting energy bands for ZnS are given in Figure 1. The large dots appearing in Figure 1 represent results of the self-consistent calculation, while the solid lines connecting these points represent a pseudopotential interpolation between these points. The forbidden region (shown hatched in Fig. 1) separates the valence and conduction bands. The top valence band has its maximum at the Γ point, while the bottom conduction band has a well-defined minimum at the Γ point. The ZnS energy bands are typical of the energy bands of the II-VI cubic compounds.

There are two primary pieces of experimental data that can be used in determining the accuracy of theoretical results. These data are the direct band gaps (the minimum energy difference between the top valence band and the lowest conduction band which occurs at the Γ point for the II-VI cubic compounds) and the experimental ϵ_2 curves determined from reflectivity or absorption data. The calculated band gap of 3.77 eV agrees very closely with the experimentally determined band gap of 3.84 eV. (6)

The ϵ_2 curves calculated from self-consistent energy bands for ZnS are compared in Figure 2 with those determined from experiments. In the figure, the solid line represents results determined from the self-consistent OPW energy bands, while the dashed lines represent the experimental curves of Baars (7) and of Balkanski and Petroff. (8) For each significant feature of the ϵ_2 curve, the region of the Brillouin zone which makes the major contribution to that feature is labeled without parentheses. The transition within parentheses gives the location of high symmetry point transitions which are not primarily responsible for the ϵ_2 feature in question. The relative peak heights are incorrect, in part, because the pseudopotential wave functions were used in calculating the transition matrix elements. The location of the peaks, not their absolute heights, is of the greatest significance in comparing with the experiment and in interpreting experimental data.

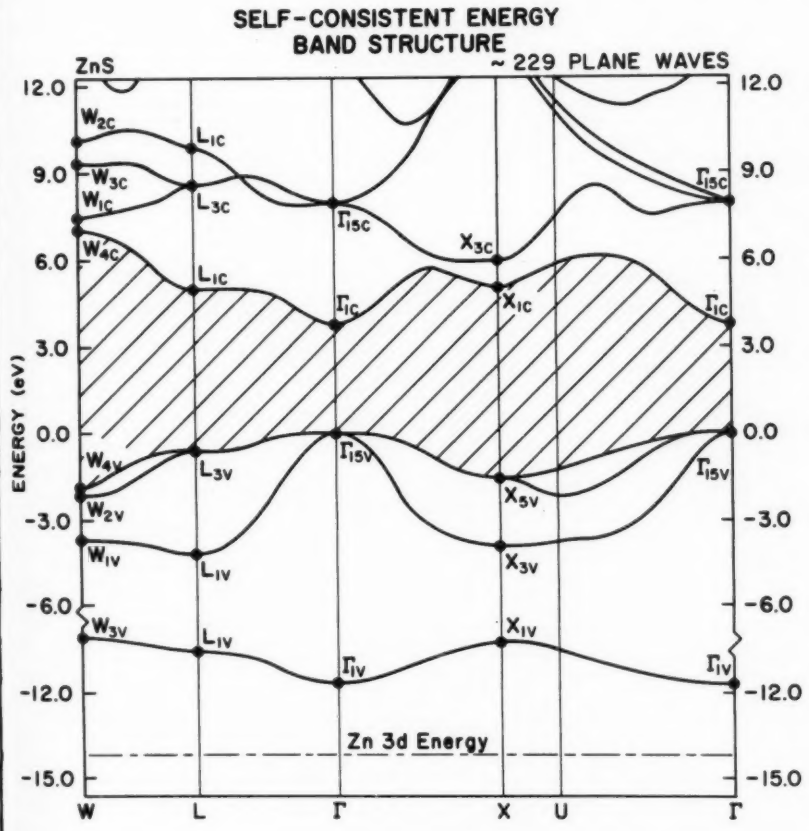

Figure 1. The self-consistent energy bands calculated with 229 plane waves are shown along selected high-symmetry lines. The heavy dots show the self-consistent results. The shape of the bands between high-symmetry points was obtained by the pseudopotential interpolation technique. The hatched region separates the valence and conduction bands. The outer d state core level is included.

The agreement between theory and experiment is within 0.2 eV for the significant peak positions. Baars attributes the peak in his ϵ_2 curve at 5.70 eV to an L_{1c}-L_{3v} transition. The theoretical results give a peak at 5.76 eV due primarily to an L_{1c}-L_{3v} transition. Baars attributes his ϵ_2 peak at 6.85 eV to an X_{1c}-X_{5v} transition, but the theoretical results show that this peak originates primarily in the U and K regions of the Brillouin zone. Balkanski and Petroff report an ϵ_2 peak at 9.4 eV, while Baars has a peak at about 9.0 eV. The theoretical ϵ_2 calculation gives a peak at 9.2 eV due to an L_{3c}-L_{3v} transition in agreement with Balkanski and Petroff and with Baars.

The ϵ_2 results for ZnS are remarkable in that peak positions are so close to the experimental values. The theoretical results provide additional information which makes it possible to determine the region of the Brillouin which is primarily responsible for the significant features in the ϵ_2 curves. These results are indispensable in explaining experimental data and hence lead to a better understanding of the properties of these semiconductors. This is just one example of how theoretical studies contribute to the fulfilling of the objectives of the Solid State Physics Research Laboratorv.

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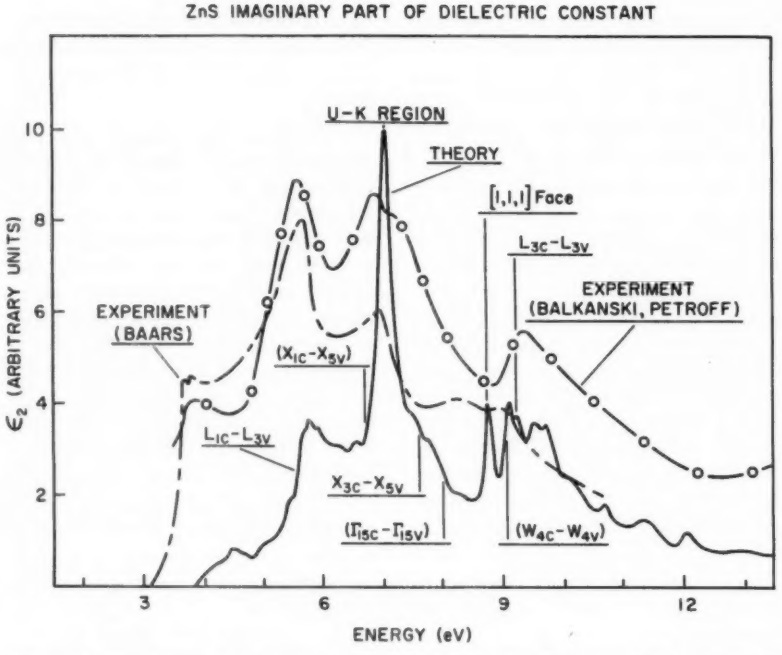
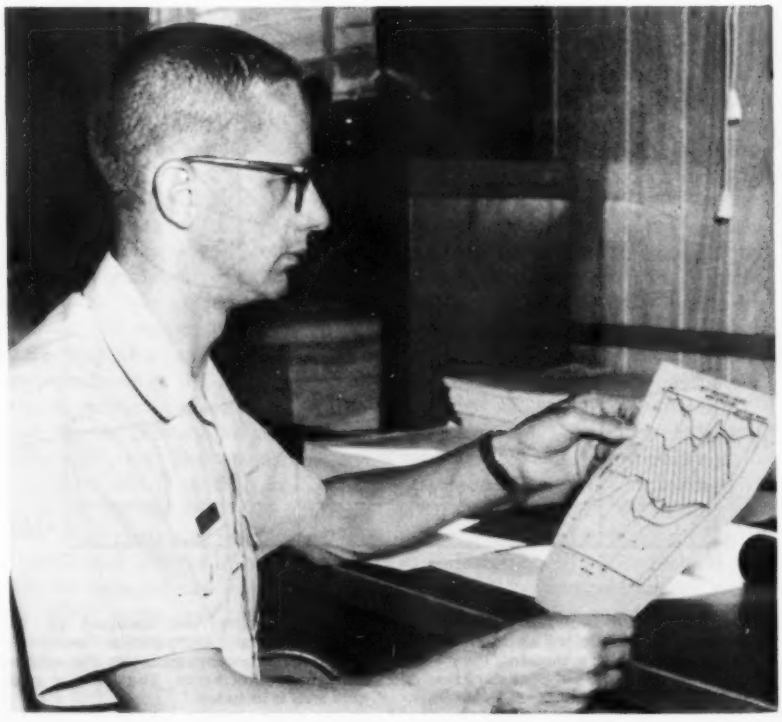


Figure 2. The theoretical and experimental ϵ_2 curves are shown with arbitrary vertical units. The indicated transitions are shown where they occur in the self-consistent calculation. The transitions in parentheses are not primarily responsible for the nearby structure. The labeled Brillouin zone regions ([111] face and u-k region) and other transitions are primarily responsible for the nearby theoretical ϵ_2 structure.



Maj Donald J. Stukel was graduated from the U.S. Military Academy in 1960, receiving a B.S. degree at the same time he was commissioned. Subsequently, in 1962, he received an M.S. in Electrical Engineering from the University of Illinois. Immediately following, he reported to the San Bernardino Air Materiel Area (AFLC) to supervise reliability activities in connection with the ICBM and space programs.

In 1965, Maj Stukel entered the Air Force Institute of Technology at Wright-Patterson AFB, Ohio, to pursue studies leading to a Doctor of Science degree. After completing all degree requirements except for the dissertation, he was assigned in 1967 to ARL's Solid State Physics Research Laboratory.

Maj Stukel is currently developing computer programs to calculate the electronic band structure of zinc-blende compounds by means of a self-consistent orthogonalized plane-wave model, using Slater's approximation for the exchange term. He is simultaneously also conducting a self-consistent OPW band calculation for ZnO which has the wurtzite structure, and planning an investigation to seek better methods of handling the exchange and correlation terms.

microprobes for medical electronics

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Basic research is often the motivation for technological advances. Such was the case in the recent development of an electronic microprobe at the Stanford Electronics Laboratories. The basic research had to do with the measurement of bioelectric potentials in the central nervous system, especially in the brain. For a variety of reasons, the current state-of-the-art in probes for this application was inadequate. Professor J. B. Angell and one of his doctoral students, K. D. Wise, under AFOSR sponsorship through the Joint Services Electronics Program, have made significant technological advances in the design and fabrication of microprobes. This important new approach utilizes the fabrication techniques of integrated circuits and microelectronics to deposit and etch layers of materials to build the probes.

The problems of measuring potentials on the cellular level in biological systems arise from the size of the cells involved and the environment in which they exist. A typical neuron is from 10 to 100 microns in diameter, and is immersed in an extracellular fluid somewhat more dilute than present-day sea water. The membrane which defines the cell is more permeable to some ions than to others, and the resulting difference in the intra- and extracellular ionic concentrations gives rise to a transmembrane potential of some 70 millivolts. A sufficient stimulus will cause the cell membrane to depolarize, with the result that a nerve impulse is propagated. Ideally, the electrode which couples this biological system to the recording amplifier should be small enough to approach a single cell closely while causing a minimum amount of damage to the surrounding tissue. Electrode-tip diameters should not exceed a few microns. Actually, electrodes used for intracellular recording must have tip diameters of less than one micron.

Due to the corrosive nature of the extracellular fluid, it is important that the microprobes be constructed from materials which are inert in the body. This is an especially important consideration for chronic (long-term) implants since many metals, e.g., copper, are known to produce toxic compounds on interaction with the extracellular electrolyte. In the work of Dr. Angell, gold has been chosen in order to avoid these hazards. Other characteristics of the biological signals which influence probe design include a dynamic signal range extending over 4 orders of magnitude from microvolts to millivolts, and a signal bandwidth from dc to about 20 kHz.

Microelectrodes in common use today are either metal electrodes or glass micropipettes. The metal electrodes are formed from electrolytically pointed metal wires, and are insulated, except for recording areas at their tips. Glass-pipette electrodes are usually filled with a saline solution so that the cell is contacted through a fluid junction at the electrode tip. However, any ion exchange between the saline solution of the micropipette and the intracellular saline solution can alter the properties of the neuron. Thus, although the pipette electrode is useful for dc and low-frequency recording, the metal electrode is generally preferred elsewhere. Unfortunately, the fabrication techniques employed for both types of conventional electrodes do not permit close control over the physical and electrical characteristics of these electrodes. This is a serious disadvantage in neurological research at the present time.

The Stanford work has been directed at the design and fabrication of single- and multiple-electrode probes which combine high spatial selectivity (small recording area and tip size), reduced electrode impedance, low noise, and wide recording bandwidth. The use of microelectronic-fabrication technology not only permits these demanding requirements to be met, but also allows the electrical and physical characteristics of the microprobes to be closely controlled. Three to 6 electrodes are common configurations for the multielectrode probes, and interelectrode spacings as small as 10 microns are possible.

In construction, the gold electrodes are electroformed on a silicon wafer using photoresist, a photosensitive acid-resistant lacquer, as a plating mask. These electrodes are then insulated by coating them with a thin film of silicon dioxide, which is selectively etched away, using conventional photoresist techniques, to form controlled recording areas at the electrode tips. The silicon carrier is then shaped by chemical etching into a form suitable for insertion into the brain. This procedure requires a well-controlled, low-temperature system for the deposition of the insulating silicon-dioxide film. A system based on the radio-frequency glow discharge technique, built by R. H. Weissman of Stanford, has been used successfully for this application. Physically, the silicon carrier in its present form consists of a rectangular portion 0.5 mm wide by 5 mm long, which serves as a mounting base for wires to the recording amplifier, and an additional length of 5 mm over which the carrier width is tapered to a tip diameter of 0.08 mm where the electrode recording areas are located. After the output wires are attached, the silicon carrier is mounted in the end of a glass capillary tube which has an outside diameter of about 1 mm. The eventual integration of source-follower preamplifiers on the carrier with the electrodes is also planned.

During the summer of 1968, completed single-electrode microprobes were tested under clinical conditions in the Department of Neurology at Stanford University. These tests showed the microprobes to be capable of recording from single nerve cells in the brain of a cat; further, they showed that the damage caused by insertion of the silicon carrier is not excessive.

studies of hydrogen-air supersonic combustion at low densities

1ST LT JAMES E. DREWRY
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Research Laboratory, ARL

A study of the supersonic-combustion simulation problem as related to high-Mach-number propulsive systems (e.g., Scramjet) is currently under way in ARL's Fluid Dynamics Facilities Research Laboratory. The method of simulation employed is considered to be suitable for fundamental studies of supersonic combustion for hypersonic flight under conditions approaching those of actual flight.

A preliminary analytical study was made to define the laboratory conditions required for adequate simulation of supersonic combustion over a wide range of flight operation, blanketing the flight corridor in the Mach 10-14 regime. (1) In conjunction with this preliminary analysis, a study was also undertaken to determine the feasibility of utilizing the major components of one of ARL's hypersonic wind tunnels for simulation studies of supersonic combustion. This study led to the development of a flexible experimental facility suitable for basic supersonic-combustion research. (2) A view of the test facility is shown in Figure 1.

The design of this facility was based on the premise that the Mach number throughout the combustor is of secondary importance, since mixing and chemical reaction are the important factors to be studied. Hence, the facility was designed to duplicate static pressure and temperature at the combustor entrance, residence time in the combustor, and relative velocity between the injected hydrogen and air streams. The laboratory injector-nozzle system chosen for the present investigation is one in which the fuel and air streams move axisymmetrically in the same direction, with the fuel (hydrogen) being injected at sonic velocity in the center of a supersonic air stream, as shown in Figure 2. The static pressures of the air and hydrogen streams are matched at the nozzle injection plane, but the static temperatures are generally different.

The problem of the mixing of two reactive gas streams is quite difficult because of the many fluid dynamic

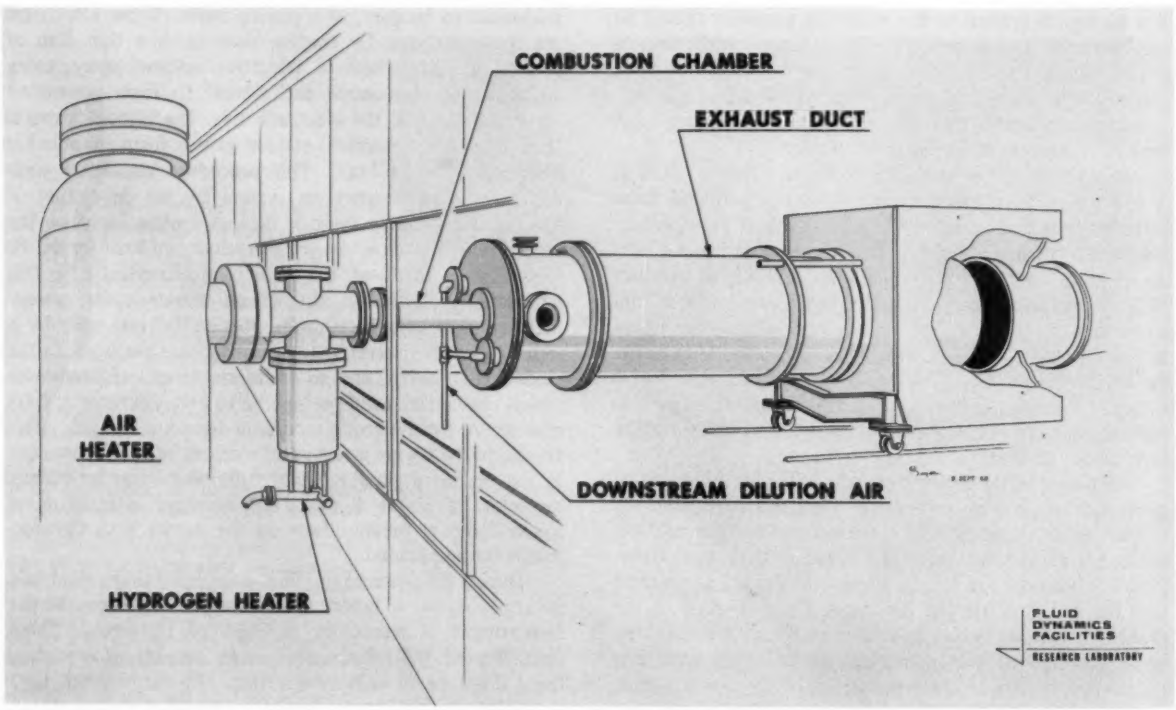

Figure 1. ARL supersonic-combustion facility.

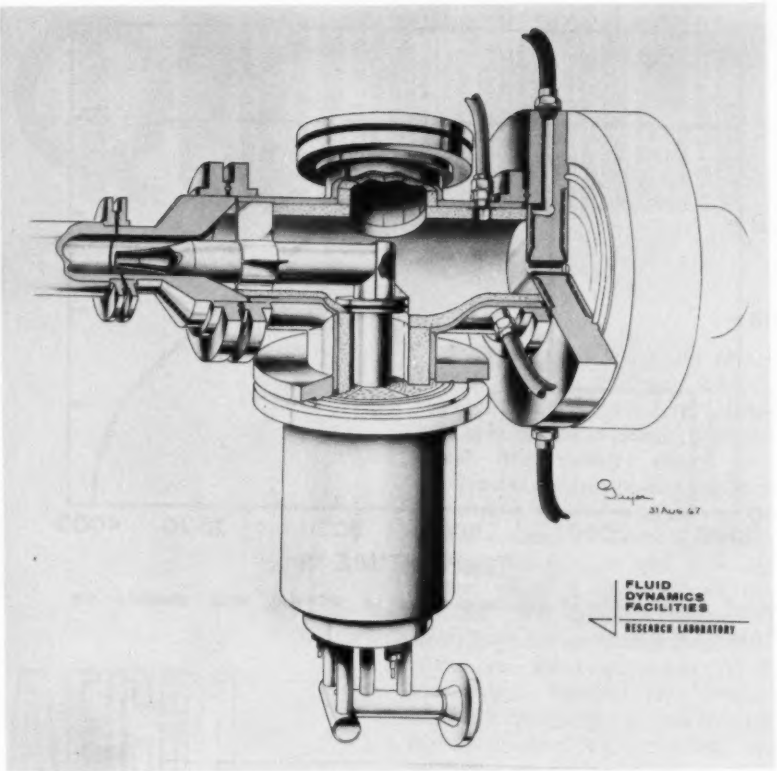

Figure 2. Supersonic-combustion fuel-injection system.

and chemical kinetic effects which are involved. In order to achieve a better understanding of the problem of supersonic combustion, as well as to establish a basis for comparison with experimental results, it was desirable to obtain analytical data on the nature of the combustor flow field. Thus, a numerical analysis of the mixing and reaction of a hydrogen-air flow system as described above has been carried out using a computer code developed by the General Applied Science Laboratories, Inc. (3) The computer program is based upon boundary-layer concepts and includes the effects of finite-rate combustion. Since the flow is ducted, an attempt is also made to account for the effect of shear at the wall. In general, the analysis provides the details of the combustor flow field necessary for the prediction of mixing and combustion efficiencies in terms of chamber geometry.

A parametric study of the supersonic-combustion problem has been performed over a Mach number range of 1.5 to 2.5 for the injected air stream. As already noted, the Mach number of the hydrogen at injection is unity. By varying reservoir conditions for a given air nozzle, it was possible to study the effect produced by a variation of the static temperature or pressure of the air at the combustor entrance. The static-pressure range of interest in the present study was between 1 and 3 psia. A value of 2 psia for the static pressure at the combustor entrance and a static temperature of 2,000° R are considered as being representative conditions for flight at an altitude of about 140,000 feet and a Mach number near 12. (1)

Some typical results of the numerical calculations are given in Figures 3 and 4 for air-jet Mach numbers of 1.5, 2.0, and 2.5 at an initial static pressure of 2.0 psia and a static temperature of 2,200° R. The calculated axial variation of static pressure downstream from the entrance to the combustor is shown in Figure 3. The sharp increase in pressure in each of the 3 cases indicates the onset of combustion. Also, it is seen that the length required for mixing and autoignition is decreased as the Mach number of the injected air stream is reduced. The calculated radial variation of static temperature at a position 3 feet downstream of the combustor entrance is given in Figure 4, where the initial temperature profile was taken as shown. As can be seen, the temperature increases significantly in the core of the flow as a result of combustion.

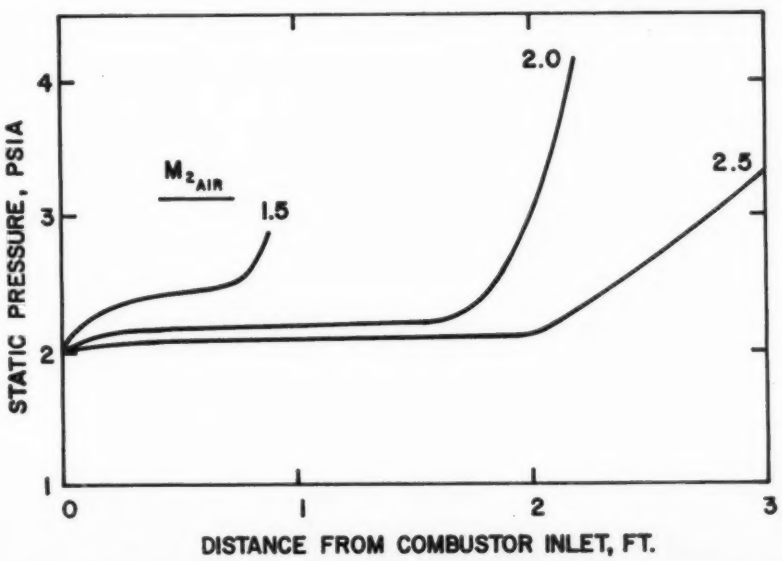

Figure 3. Axial variation of static pressure for supersonic combustion in a constant-area duct.

To date it has not been possible to

run experimental tests with initial conditions exactly matching those of theoretical cases which predicted appreciable combustion in a given combustor length. However, the experimental results obtained so far, along with the results of the parametric study, have indicated the direction to be taken in an effort to achieve adequate laboratory simulation of supersonic combustion for high-Mach-number flight conditions.

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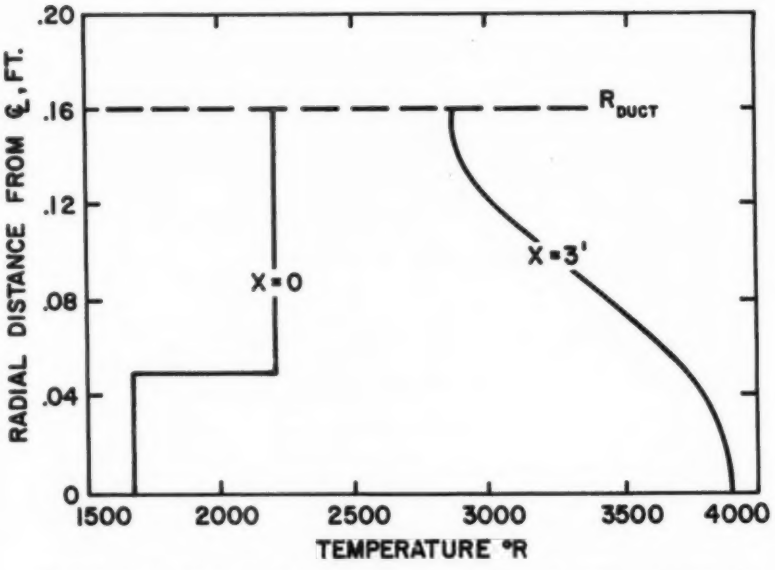
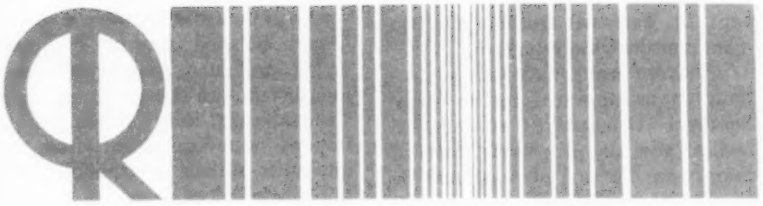


Figure 4. Radial profiles of static temperature at different axial positions for $M_{2\,AIR} = 2.5$.

1st Lt James E. Drewry was graduated from the University of Virginia in 1960 with a B.A.E., receiving his commission as a 2nd Lt at the same time through the Air Force ROTC program. Before entering active duty, he did graduate work in aerospace engineering at the University of Virginia and at the University of Toronto, receiving his M.A.E. at the former in 1962, and his Ph.D. at the latter in 1967.

Lt Drewry was assigned to the Fluid Dynamics Facilities Research Laboratory at ARL in February 1967. In his present capacity, he does research in hypervelocity-flight duplication, concentrating particularly on studies of supersonic combustion as related to Scramjet design and operation. Lt Drewry also monitors research being conducted under contract in electromagnetic heat addition and the acceleration of gases. He is a member of Sigma Xi and the American Institute of Aeronautics and Astronautics, and has several publications to his credit.



AFCRL research briefs

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES

Diamond From Marsh Gas: Under AFCRL contract, Professor John C. Angus at Case Western Reserve University has succeeded in growing diamond crystals from methane (marsh gas). The process involves passing methane gas slowly over a diamond seed crystal at temperatures of about 2,000° F. The gas decomposes and gives off carbon, which is deposited on the diamond seed crystal. The carbon atoms from the gas arrange themselves in the same atomic pattern as that of the original diamond seed crystal. Curiously enough, the process requires that the diamond be grown at very low pressure–only 0.001 atmosphere. This is in contrast to the very high pressures which have been used for the past 10 years to synthesize diamonds in the laboratory. AFCRL is interested in diamond because of its semiconducting properties. As a semiconductor, diamond can operate at much higher temperatures, and is more resistant to ionizing radiation that germanium or silicon semiconductors. (Solid State Sciences Laboratory)

Rapidly-Changing Playas: Last year, Capt. James T. Neal of AFCRL published a comprehensive report on dry lakebeds (playas) entitled "Changing Landforms in the Southwestern U.S." He noted in the report that dry lakebeds are the most changeable of all geological landforms. Even so, it is surprising that so many changes can take place in the period of three or four years. AFCRL has explored most of the major dry lakebeds in Arizona, California, Utah, and Nevada, and has catalogued scores as suitable for use by the Air Force as emergency landing fields. AFCRL is presently resurveying many of the dry lakebeds previously investigated. Four of these, Coyote, Troy, Lucerne, and South Panamint, all in the Mojave Desert region of California, have undergone striking surface changes since last surveyed. Three of the playas–Lucerne, Troy, and Coyote–which in 1964 were characterized by moderately soft, puffy, well-aerated soil which could be crossed by car with difficulty, have turned into hard-surfaced playas characterized by cracks and fissures. In addition, vegetation has spread over wide areas of the Coyote playa. The South Panamint playa, last surveyed in 1966, appears to be rapidly converting from a hard-packed playa to one with a puffy, soft surface. Large irregular areas of puffy ground have developed on the hard surface since 1966, with the areas of puffy soil being as large as several hundred feet across and having a microrelief ranging from one to four inches. Widespread and extensive flooding is the probable cause for the conversion of soft soil to hard soil with a fissure-prone surface. The conversion of hard-packed soil to soft, puffy soil is probably caused by ground water seeping upwards through capillary processes. (Terrestrial Sciences Laboratory)

Record Altitude for Dart Sounding System: Three Viper-Dart rocket vehicles were recently flown at altitudes of between 375,000 and 400,000 feet at Cape San Blas, Florida. These altitudes are the highest ever recorded for this type of rocket system where a booster rocket motor imparts sufficient energy to a slender, 2-inch-diameter, dart-like inert projectile for coasting flight from 15,000 feet (where the motor drops away) to 400,000 feet. In each of the flights, a ROBIN payload, a passive spherical balloon, was successfully ejected at apogee and tracked by radar as it fell, in order to measure atmospheric density and winds. Final development of the Viper-Dart system could cut rocket costs to half those of the more conventional rocket designs where all or part of the propulsive system must be lofted to apogee. This system is being designed and developed for eventual operational meteorological use by the Space Data Corporation of Phoenix, Arizona, under an AFCRL contract. (Aerospace Instrumentation Laboratory)

THE GREAT 30 DORADUS NEBULA

SPACE PHYSICS
LABORATORY, AFCRL

The completion of the Cerro Tololo Observatory in Chile last November found astronomers standing in line with a long list of observational programs. Because few high-resolution telescopes are located at excellent seeing sites in the Southern Hemisphere, nearly half the heavens are waiting to be viewed in clear detail. AFCRL and the Yerkes Observatory initiated the Cerro Tololo project back in 1958, with AFCRL contributing the initial funding. For this reason, AFCRL--more specifically, Dr. Gordon Wares--was given the privilege of making the first observations at Cerro Tololo. Consequently, in two separate trips, Dr. Wares has thus far spent two months at the Observatory.

With so many outstanding questions to be answered for so many Southern Hemisphere astronomical bodies, how did Dr. Wares establish priority for his first observations? He chose first to observe the Great 30 Doradus Nebula in the Clouds of Magellan. This nebula, a fairly dense gas cloud, has no known counterpart in our galactic system. Its mass is estimated to be that of 5 million suns. It seems to have an intricate system of wisps and filaments indicating density fluctuations. The question that Dr. Wares and his colleague, Dr. L. H. Aller of UCLA, hoped to resolve was whether or not the chemical composition of this unique object differed from that of bodies in our own galaxy.

For the study, the 36-inch Cerro Tololo telescope (one of the 5 telescopes at the Observatory) was used to obtain emission spectra. Photometrically calibrated spectrograms were interpreted with the aid of spectra of standard stars. Relative ionic concentrations were calculated from the intensities of their corresponding emission lines and expressed in terms of the ratio of the ion to hydrogen. Helium, oxygen, neon, and sulphur were studied in the following ionic states: He^{+}, O^{+}, O^{++}, Ne^{++}, S^{+}, S^{++}.

Of course, it would be exciting to report that the Great 30 Doradus Nebula has some distinctive chemical composition. Wares and Aller did not find this, however; nor did they really expect to. They found that, for helium, oxygen, neon, and sulphur, the abundances appear normal--that the composition is essentially the same as that of stars belonging to population Type I in our galaxy.

Information Sciences:

AN IMPROVED PERSONAL PORTABLE MICROFICHE READER

DR. HAROLD WOOSTER
Director of Information Sciences
AFOSR

The recent announcement by the Defense Documentation Center that DDC users who want full-sized reports will have to pay $3.00 for each, and that only microfiche copies of these reports will be available without charge, has again emphasized the need for truly effective microfiche readers.

Microfiche (from the French for small sheet) is a form of microphotography which uses multiple images on sheet film instead of the more familiar reel microfilm on 16- or 35-mm cinema film stock. Microfiche has many advantages over the conventional microfilm. Reproduction, once the original negative is made, can be accomplished by devices as simple as a contact printing frame. Filing, and locating the desired item, is not much more difficult than with simple file cards.

But microfiche has one major disadvantage which doesn't show up until you start looking at it. There are several excellent reader-printers on the market which cost upwards of $1,000--too expensive for any installation to have more than one or, at most, two. There are an even greater number of "portable," "personal" viewers on the market, ranging from an inexpensive folding cardboard, magnifying-lens contraption to a class of bulky devices--bulky in the sense that they won't fit into a moderately stuffed briefcase--requiring 110 volts house current to use. In practice the scientist/user, presented with a copy of microfiche by *force majeure*, either goes to the nearest reader-printer and converts it to hard copy, at a cost several times greater than the original printing cost would have been, or tosses it away as being too troublesome to use.

If microfiche is to be met with anything other than sullen resistance, the viewer must be not much more difficult to use than the original publication. A reader meeting this requirement has been designed by the author, not as the basis for an RFP, but as a challenge to the industry. Its specifications are as follows: *Size*--not greater than 8½ x 11 x 1½ inches; *Power source*--self-contained nickel-cadmium batteries, built-in charger, alternate 110-volt use; *Case*--molded of high-impact plastic, Cyclolac ® or equivalent; *Screen size*--5 x 7"; *Controls*--one full motion moves image one frame in either X or Y direction and mechanical counters give row and frame numbers; *Ambient light*--usable from bright sunlight to total darkness.

The limiting dimension in this design is the thickness; the rest is conventional good camera practice. It may be difficult, but not impossible, to get the necessary magnification in a total of less than 1.5-inches throw without going to plastic extreme fish-eye lenses acting on anamorphic microfiche images--i.e., the image distorted with higher magnification the further from the center. If so, one can always resort to a folding hood *cum* viewing screen.

A viewer meeting these specifications may never be built. That is unimportant. What is important is that microfiche readers be built for the convenience of the user, and not for the convenience of the designer.

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Figure 1.
Personal microfiche reader.

DIVE-ANGLE INDICATOR FOR FIGHTER AIRCRAFT

AEROSPACE INSTRUMENTATION LABORATORY

AFCRL

Soon to be tested by the Tactical Fighter Weapons Center (TAC) at Nellis AFB, Nevada, is a novel dive-angle indicator. This simple instrument was originally designed by AFCRL for a quite different purpose. Here is the background: In 1966, AFCRL began a large observational program to obtain data on the percent of time that the ground below and the sky overhead are visible to an aircraft pilot or observer. Some 72,000 in-flight observations were made for AFCRL by pilots of SAC, MAC, Pan American Airlines, and others. These data, arranged by geographical location, aircraft altitude, look angle, and season, were subsequently published in a report by Eugene A. Bertoni of AFCRL ("Clear Lines of Sight from Aircraft," *AFCRL-67-0435*).

The program had one weakness. Observers were asked to estimate the look angle, and thus precision was lost due to judgment errors. For the second and larger phase of the program, which got under way earlier this year with the help of several airlines, the RAF, and various Air Force commands, this deficiency was corrected.

AFCRL designed a small look-angle indicator, which it called a clinometer, and contracted for its production. More than 2,000 of these clinometers were produced at a cost of about $4 each. AFCRL has distributed these clinometers widely to all those participating in the observational program.

The present model of the clinometer was invented by Norman L. Smith of AFCRL. It is ingeniously simple. Its basic element is a triangular-shaped tube partially filled with liquid encased in clear plastic. When the tube is tilted, the liquid moves through the tubes forming the sides of the triangle. On one side of the plastic case surrounding the triangle there are calibration marks to indicate the angle at which the clinometer is tilted. The liquid in that portion of the tube moves downward as the negative angle increases, with the top of the column of liquid indicating the degree of dive achieved.

TAC plans to test the clinometer as a dive-angle indicator in the F-100, F-105, and F-4 aircraft. AFCRL is redesigning the clinometer so that the dive angle can be clearly read in bright sunlight. The redesigned clinometer will also emphasize resolution of negative angles of 20 to 45 degrees which are critical in dive-bombing. The clinometer will be installed alongside the gunsight and will be readable at a distance of 3 feet.

Norman L. Smith of AFCRL examines a model of the dive-angle indicator which he designed for tests aboard the F-100, F-105, and F-4 aircraft.

Mr. Norman L. Smith's career started in personal, private enterprise in 1925. For many years this involved machine-shop operations for repairing and modifying equipments used in his business. In 1941, wishing to make a more direct contribution to the war effort, he attended Lincoln Trade School, and joined the Allis-Chalmers Manufacturing Company at Hyde Park, Mass., where he remained until July 1942. He then transferred to the General Motors Corporation plant in Bristol, Conn. Later, from February 1943 to October 1945, he was employed by the Radio Research Laboratory of Cambridge, Mass.

Mr. Smith's broad experience then came to the attention of the Watson Laboratories, which he joined in November 1945. By a process of evolution over the years, this organization became the present Air Force Cambridge Research Laboratories. Thus, Mr. Smith rounded out 23 years of continuous service with this organization by November 1968.

Since the Korean War, Mr. Smith has been, first, the General Foreman of the Geophysics Research Directorate Experimental Shops and, for the past several years, the General Foreman of the Experimental Shops of AFCRL. In these capacities he has contributed many creative ideas to the tasks under his supervision. A significant number of these have been recognized through patent procedures as being inventions of substantial value to the Air Force.

USE OF HELICOPTERS TO DISSIPATE WARM FOG

METEOROLOGY LABORATORY AFCRL

To clear warm fog or low stratus clouds from a runway or a bombing target, three approaches are available—and all have been tried in one form or another. We can increase the air temperature, thereby increasing the capacity of the air for water vapor; we can seed the fog or cloud layer with some kind of condensation nuclei; or we can mix the saturated air with the drier air from above.

AFCRL, in experiments involving the third approach, has reported notable success in clearing large holes in stratus clouds. Such clouds and warm fog are structurally similar. The mixing of the drier air and the lower saturated air was done by the simple method of hovering a helicopter above the cloud layer. In experiments conducted earlier this year at Eglin AFB, Florida, holes 600 feet in diameter were made in 1,000-foot-thick stratus clouds in less than a minute. The experimental program is under the direction of Vernon G. Plank of AFCRL.

Under procedures for optimum clearing specified by Plank, the helicopter hovers at 100 feet above the cloud or fog until an initial opening appears, and then ascends until the maximum clearing width is observed. Then the helicopter slowly accelerates across the cloud or fog until an optimum clearing rate is attained. The clearing rate depends primarily on the gross weight of the helicopter and on the lift-loading characteristics of its main rotor. The HH-53B Super Jolly Green Giant helicopter was used in the AFCRL tests.

In the case of thick fogs or low clouds, openings will drift with the wind and, in many circumstances, refill in less than 10 minutes. Best results should be obtained with ground fog less than 100 feet thick. The diameter of the clearing may be greatly increased because the ground increases turbulence and spreads the dry air radially outward across the ground surface.

The method requires that the relative humidity of the drier air be 90 percent or less. If the air above the cloud or fog layer has a higher humidity, the mixing might actually deepen the fog.

Curiously enough, the earliest and best-known approach to the warm-fog-dissipation problem also involved the mixing of the fog with drier upper air. In these early experiments dating from World War II, oil or kerosene was ignited alongside the runway to raise the air temperature, thereby increasing the air's water-vapor capacity. In addition, the heat set up convection currents which transported the moisture-laden air to higher elevations where the moisture evaporated after mixing with the drier air.

More recently, AFCRL and others—notably, the United Airlines in experiments conducted in California—have attempted to seed warm fog with pulverized salt. Moisture condenses on these salt particles, thus clearing holes in fog layers. This condensation-nuclei approach may yet yield a feasible technique, although results to date have not matched the effectiveness of AFCRL's helicopter-hovering technique.

The dissipation of warm fog is far less tractable than is the dissipation of supercooled fog or clouds. (Supercooled fog and clouds, fairly common winter phenomena, contain droplets in the liquid state at below-freezing temperatures.) In experiments conducted several years ago, AFCRL demonstrated that large holes could be made in supercooled clouds by seeding them with dry-ice pellets.

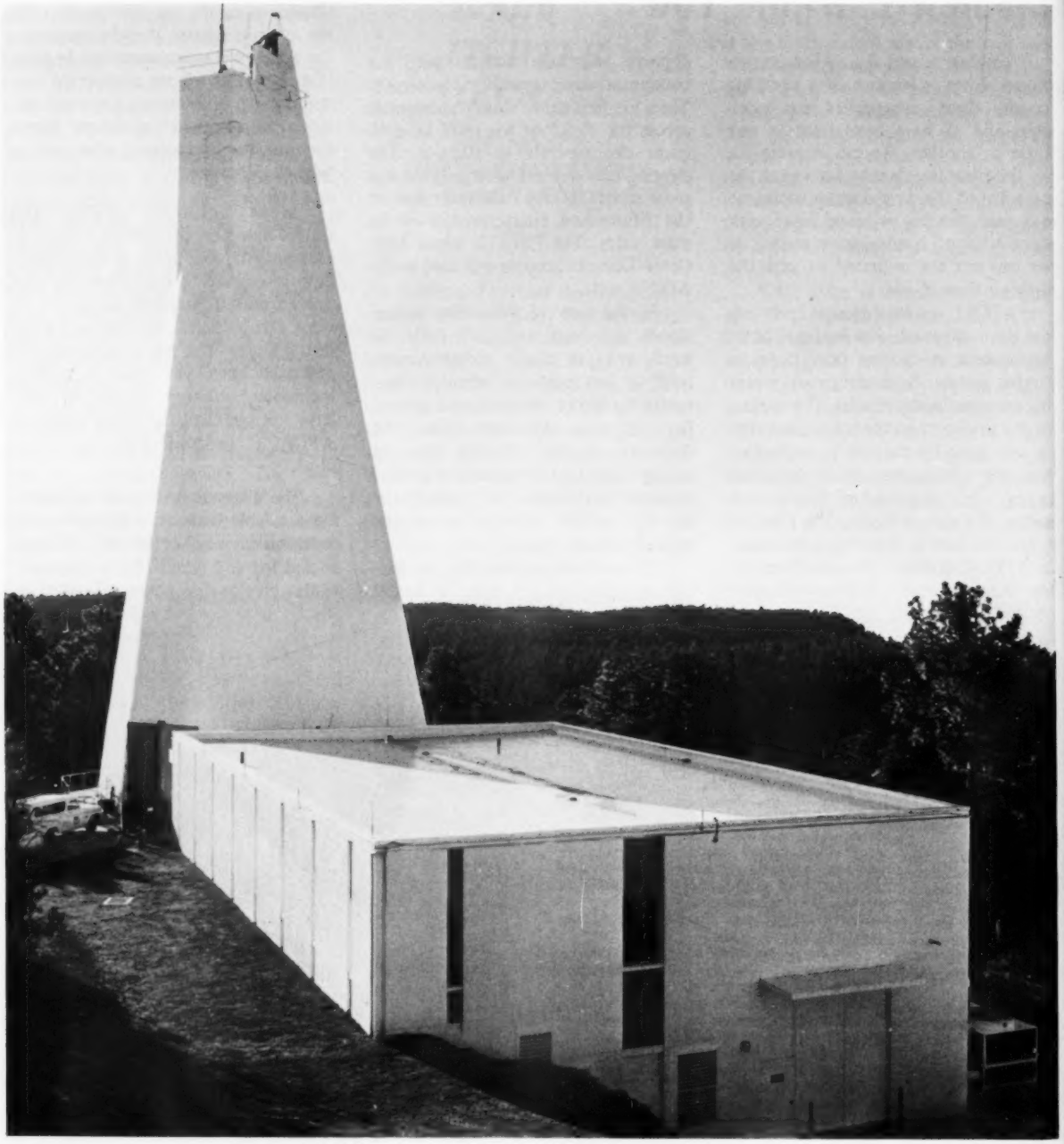
Mr. Vernon G. Plank is an atmospheric physicist in the Cloud Physics Branch of AFCRL's Meteorology Laboratory where, since 1951, he has conducted research in radar meteorology and cloud physics. He has been especially concerned with the radar characteristics of clouds, spurious echoes on radar, the refractive-index structure of cloudy regions, and cloud effects on the radio guidance of space vehicles.

In the period 1947-51, Mr. Plank was a meteorologist with the U.S. Navy Electronics Laboratory in San Diego, Calif., where he did research on special meteorological instrumentation and on the meteorology of radio-wave propagation. He received his A.B. in Meteorology from the University of California at Los Angeles in 1949, and his M.S. in the same field from the Massachusetts Institute of Technology in 1954. He has also completed all the requirements for a Ph.D. in Meteorology, except for the dissertation.

Mr. Plank is the author of a number of publications, and is a member of three professional societies.

Mr. Plank examining the cloud wake trails produced by the HH-53B helicopter.

Dedication of new Sacramento Peak telescope set for May 15, 1969



AFCRL's new solar vacuum telescope at Sacramento Peak, N.M., under construction since April 1966, will be dedicated on May 15, 1969. At that time, the telescope will be fully instrumented and in operation. More than 100 Air Force and other military officials, civic officials, and members of the press will be invited to the dedication. The invitation list will include the Air Force Chief of Staff, the Secretary of the Air Force, the Director of Defense Research and Engineering, and the heads of a number of military R&D laboratories as well as congressmen from New Mexico.

The new AFCRL vacuum tower telescope will give the Sacramento Peak astronomers a unique instrument having the best resolution of any solar telescope in the world. The telescope is 330 feet in vertical length, with a 200-foot portion beneath the ground. The entire center section, an evacuated chamber 3 feet in diameter and 300 feet long, floats and rotates on a pool of mercury.

GP O 870-249